EXPERIMENTAL INVESTIGATION OF ORGANIC COMPOUND STABILITY UNDER HYDROTHERMAL CONDITIONS

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ABSTRACT

Hydrothermal systems are the most likely locations on the early Earth for the emergence of life due to the abundant chemical energy inherent in the characteristic disequilibrium of these environments. Hydrothermal conditions are theoretically favorable for the formation and stability of organic compounds; we are investigating this hypothesis experimentally. Initial experiments with amino acids at 250°C and 250-350 bars have yielded ammonia, carbon dioxide and carboxylic acids as the main reaction products. While the amino acids decomposed rapidly, the ratios of the products remained constant during the course of the experiments, in agreement with field and experimental observations of other metastable organic states, as well as with calculated organic compound metastability. Further experiments are currently underway and the results will be presented.

INTRODUCTION

Hydrothermal systems are the most likely locations on the early Earth for the emergence of life (1-3). Because of the disequilibrium inherent in such dynamic, mixing environments, abundant chemical energy would have been available for formation of the building blocks of life. In addition, theoretical and experimental studies suggest that organic compounds in these conditions would reach metastable states, due to kinetic barriers to the formation of stable equilibrium products CO_2 and methane (4-7). The speciation of organic carbon in metastable states is highly dependent on the oxidation state, pH, temperature, pressure and bulk composition of the system. The goal of our research is to investigate experimentally the effects of a number external variables on the formation, transformation, and stability of organic compounds at hydrothermal conditions. We have begun work to attempt to control the oxidation state of simulated hydrothermal systems by using buffers composed of mineral powders and gas mixtures. We are also beginning to test the stability of organic compounds under these conditions. The experiments are being performed using a hydrothermal bomb apparatus at the U.S. Geological Survey in Menlo Park, CA (Figure 1) and a supercritical water oxidizer (SCWO; Figure 2) at NASA Ames Research Center in Moffett Field, CA.

EXPERIMENTAL

Initial experiments have been performed using the hydrothermal bomb set-up to test amino acid stability at 250°C and 250-350 bars. In order to attempt to control the oxidation state inside the experimental cells, we added mineral powders to sample cells, along with distilled, deionized water. Two different mineral assemblages were used in two different experiments; pyrite-pyrrhotite-magnetite (PPM) and iron-iron oxide (FeFeO). The cells were then sealed, heated, and pressurized. The bomb assemblies were rocked to ensure continual contact between the solution and fresh mineral surfaces, and the buffers were allowed to equilibrate over a period of weeks. Amino acids were then added to the reaction vessels, and the system was sampled at regular intervals.

The set-up available at NASA Ames Research Center for this work consists of a supercritical water oxidizer, or SCWO, previously used to oxidize waste organic matter to CO_2 and H_2O. Work is currently underway to restore the SCWO to operational status. A schematic diagram of the SCWO is shown in Figure 2.

Because the SCWO is a flow-through apparatus, we can simulate the dynamic mixing environment characteristic of hydrothermal systems. Solutions of differing compositions and temperatures can be combined to investigate the potential for organic compound synthesis or stability. The oxidation state will be controlled using gas mixtures, allowing evaluation of the catalytic effect of minerals which will be added to the reaction vessel.

PRELIMINARY RESULTS

In the experiments conducted using the hydrothermal bombs, the amino acids decomposed rapidly, but yielded ammonia, carbon dioxide and carboxylic acids as the main reaction products. The ratios of the products remained constant during the course of the experiments, in agreement with field and experimental observations of other metastable organic states[4,6], as well as with calculated organic compound metastability. Further experiments of this type are currently underway and the results will be presented, along with some preliminary results from our initial SCWO experiments.

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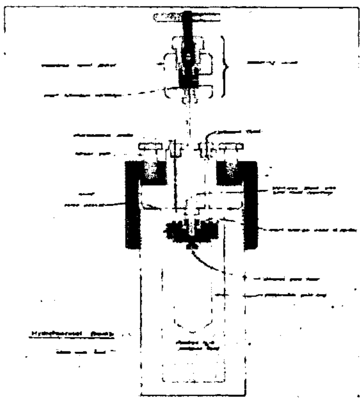

Figure 1. Schematic diagram of the hydrothermal bomb apparatus used for organic compound stability experiments.

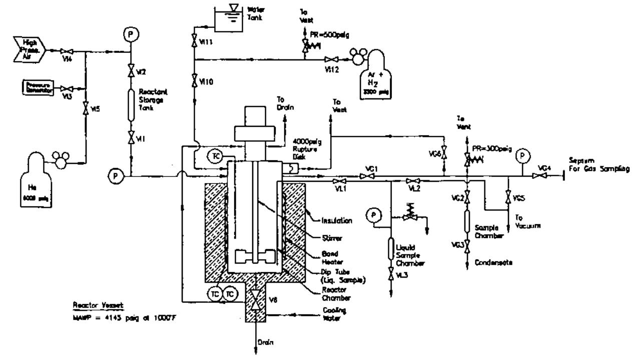

Figure 2. Schematic diagram of the supercritical water oxidizer (SCWO) used for organic compound stability experiments.